Phase I SBIR Final Report

Durability of Turbine Engine Materials

Advanced Materials Test Methods for Improved Life Prediction of Turbine Engine Components

Brystin Research and Development Incorporated
and
The University of Dayton

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Phase I final report developed under SBIR contract for Topic # AF00-149, "Durability of Turbine Engine Materials /Advanced Material Test Methods for Improved Life Prediction of Turbine Engine Components. All tasks were completed which included:

1) Customer Needs analysis
2) Develop and demonstrate a functional DCPD software module of WinMATE 2000, including all support system modules.
3) Demonstrate WEB based training method and features for WinMATE training tools.
4) Develop a commercialization strategy and alliances.

The WinMATE DCPD software module was demonstrated as well as all of the supporting modules required to set up test parameters, communicate with data channels, display real-time data, and store configurations and data for later retrieval. The training requirements have been studied and a functional, web-based example of the learning tool was constructed and demonstrated.
The work completed during Phase I of this effort has culminated in a strategic plan to meet the Phase II project objectives. We have demonstrated the technical feasibility of creating full-scale versions of the WinMATE software and learning tools. We have demonstrated the commercial feasibility of the WinMATE technology and developed commercial alliances market entry.

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Introduction

This final report for the Phase I SBIR project entitled "Advanced Materials Test Methods for Improved Life Prediction of Turbine Engine Components" includes a summary of the work performed under each task in the Phase I proposal. The format follows the outline of the Phase I proposal addressing the work accomplished, the findings, and the deliverables for each proposed task.

The major issues addressed in Phase I were as follows.

1) Identify and understand the potential user base so that the WinMATE 2000 system and training program will satisfy the overall commercial need and provide for the development of a viable, stable and successful program.
2) Develop and demonstrate a functional DCPD module of WinMATE 2000, including all support system modules.
3) Develop an understanding of the system and user base to design and set-up the training methodology
4) Demonstrate the training method and features.
5) Develop a commercialization strategy and alliances

All tasks set out in the Phase I proposal have been completed. The WinMATE DCPD software module was demonstrated as well as all of the supporting modules required to set up test parameters, communicate with data channels, display real-time data, and store configurations and data for later retrieval. The training requirements have been studied and a functional, web-based example of the learning tool was constructed and demonstrated. Dialog box displays taken directly from the WinMATE DCPD software module were used for this web-based demonstration.

The work completed during Phase I of this effort has culminated in a strategic plan to meet the Phase II project objectives. We have demonstrated the technical feasibility of creating full-scale versions of the WinMATE software and learning tools. We have demonstrated the commercial feasibility of the WinMATE technology by obtaining substantial commitments from Phase II commercial partner(s) and by performing a preliminary market analysis. Finally, we have prepared and submitted a comprehensive Phase II proposal incorporating all the information and knowledge gained in Phase I.

Needs Analysis

Gaining a comprehensive understanding of the WinMATE customer base (including their usage and training requirements) was the first task in the phase I project. Customers, in this context, comprise all organizations and individuals who are, or have the potential to, benefit from the WinMATE development process or the end product. The resulting customer analysis was, and is being, used to document and direct the WinMATE software and training development efforts to ensure that all of the customer's needs are addressed appropriately.

We began the analysis by documenting all of the customers associated with the development and/or use of a material test system – managers, developers, marketers, trainers, end users, and others. We spent a considerable amount of time working with, talking to, gathering information from, and studying these customers and the best ways of meeting their needs. From this work three major need matrices were developed. Summaries of these need matrices are presented in the <u>*Customer Needs Matrices*</u> section below.

Customer identification

A comprehensive list of current and anticipated managers, developers, marketers, and end users has been compiled with a description of both their common and individual needs in developing and using the WinMATE system. Each customer interacts with the overall strategic development plan at some level in one or more areas. Accordingly, each customer has been evaluated and prioritized with respect to the level at which they interact with the overall plan and their needs at each of these interaction points. The various customers and their salient characteristics are described in the paragraphs below.

AFRL/MLLMN

AFRL/MLLMN is the principal research user of the WinMATE system. The researchers represent customers who have user needs, development needs, and commercialization needs. The commercialization needs arise from the fact that successful research development of WinMATE 2000 and related technologies will require some minimum level of commercialization success to provide the needed research development funding.

In addition to research uses, AFRL/MLLMN has been one of the primary sources of testing experience and information integrated into the WinMATE system. They also function as a *de facto* source of code testing since they are usually the first to use the software in a real-world laboratory setting. Thus, AFRL/MLLMN has a need for its contributions to be recognized in a way that is clearly visible to the other end users.

The University of Dayton Research Institute (UDRI)

The UDRI is the prime developer of the WinMATE software system. The UDRI requires resources for software code development, software educational learning tool development, and a commercial partner to manage and commercialize the WinMATE package. WinMATE sales, installation, training, and maintenance capability in the commercial partner will be built on the current technical expertise of the UDRI. As WinMATE becomes more commercial in nature and more commercialized in form, we visualize the emergence of two, parallel activities. The first will be tailored toward research and development and will be the primary responsibility of the UDRI. The second will be tailored toward commercializing the research developments and supporting the existing customer base and will be the primary responsibility of the commercial partner. These activities will be closely linked via agreements between the UDRI and the commercialization partner.

Commercialization Partner

The Commercialization Partner (marketing and sales) needs a commercially useful and stable software system that can be installed on a generic PC platform and that can be integrated with both existing and new hardware. This software system must provide the end-use customer base with a reliable test platform that is easier to use, more functional, and more powerful than current test systems and methods. The potential market for this type of product ranges from research lab environments to manufacturing companies requiring high-volume, standardized tests on a daily basis.

Trainers

Trainers are required to introduce the system, the standards, the material properties, the hardware, and the software to the range of end users. In addition, they are responsible for describing and demonstrating analysis tools and documentation systems. Training requirements vary with the testing goal, the users expertise, and the specific application.

General User Characteristics

The projected general user base for WinMATE has a wide educational background and varying expertise level. The end user's applications range from product inspection and testing to materials research. The industrial product testing market often requires a rather simple test setup that is repeated many times with little or no need for configuration changes. These tests must generally be performed according to standardized procedures and have well-defined data and documentation requirements. The materials research market, in contrast, requires a full-featured system with the ability to change almost every test parameter, record and analyze large amounts of data, and change test parameters during the test. Between these two extremes are combinations of different levels of user experience and different end user testing goals.

Customer Needs Matrices

Three different matrices of needs result from viewing the WinMATE customer base from three different perspectives. Management needs, technical needs, and training and information needs comprise the requirements to produce a system and package that can be used and marketed to the various end users. In this case we are evaluating and setting requirements for a system that has multiple users with multiple applications working in multiple industries. The development effort must therefore be directed to multiple, tailored end products - preferably all based on the same basic platform.

Management Needs

The management needs address the basic performance issues of a development program and list the areas of performance requirements. The customers are therefore those involved in the development. A summary of the management needs matrix is presented in Figure 1. The first four requirements in Figure 1 are technical and describe the overall function of the system. All of these requirements basically describe the performance quality of the final package.

User	Reliability	Accuracy	Functionality	Usability	Marketability	Expandability	PC Generic Platform	Closed Architecture	Open Architecture	Test Documentaiton	Training Program
AFRL/MLLMN	X	X	X	X	X	X	X		X	X	X
UDRI	X	X	X	X	X	X	X		X	X	X
BRDI	X	X	X	X	X	X	X			X	X
Research Laboratories	X	X	X	X	X	X	X		X	X	X
Production Laboratories	X	X	X	X	X	X	X	X		X	X
Marketing	X	X	X	X	X					X	X
Trainers	X	X	X	X						X	X
End User	X	X	X	X			X			X	X
	Areas of Need										

Figure 1. WinMATE 2000 Management Needs Matrix.

There is an expressed need for at least two end products – one with open-ended architecture to address research users and one with a closed architecture to address production users. From the commercialization aspect, making the products as similar as possible will reduce marketing, installation, and maintenance needs. One scheme would be to maintain a continually evolving beta version available to research license holders and periodically release a mature, stable version to commercial license holders. The commercial version would not include all the latest enhancements. This is just one of many possible arrangements that must be evaluated in the Phase II effort.

Technical Needs

The technical needs matrix in Figure 2 shows the technical issues that must be addressed to satisfy the end user requirements for a system that will be routinely used to test and evaluate material properties. The research system requires a much more open architecture as well as the ability to efficiently modify operational code. The industry version requires a static version that can be marketed, sold, maintained, and periodically upgraded.

User	Reliability	Accuracy	Functionality	Usability	Marketability	Expandability	PC Generic Platform	Closed Architecture	Open Architecture	Test Documentaiton	Training Program
AFRL/MLLMN	X	X	X	X		X	X	X	X	X	X
UDRI	X	X	X	X		X	X		X	X	X
BRDI	X	X	X	X		X	X			X	X
Research Laboratories	X	X	X	X		X	X		X	X	X
Production Laboratories	X	X	X	X		X	X	X		X	X
Marketing	X	X	X	X						X	X
Trainers	X	X	X	X						X	X
End User	X	X	X	X		X	X	X	X	X	X
	Areas of Need										

Figure 2. WinMATE 2000 Technical Needs Matrix.

Training and Information Needs

The training and information needs shown in Figure 3 follow from the overall potential capabilities of the WinMATE system. Again, we have customers of many different expertise levels and backgrounds. Training applications range from novice to expert and applications range from single variable set-up to very complex test arrangements. Training on a complex system with many different applications, users, and capabilities requires a training system that teaches, trains, and provides information in many different ways and formats.

User	PC Based	Web Based	Materials Reference	Standards Reference	Overview and Introduction	Basic Training	Advanced Training	Expert Training	Step-by-Step Training	Tutorial	Lecture Series	Industrial Links	Publications
Lab Engineers	X	X	X	X	X	X	X	X	X	X	X	X	X
Lab Technicians	X	X	X		X	X	X	X	X	X	X	X	X
Industrial Engineers	X	X	X	X	X	X	X	X	X	X	X	X	X
Industrial Technicians	X	X		X	X	X			X	X			
University Professors	X	X	X	X	X	X	X	X	X	X	X	X	X
	Areas of Application												

Figure 3. WinMATE 2000 Training Needs Matrix.

Test documentation, analysis, and reporting are very important issues across all users and applications. Training is also a significant issue with all applications and users. Training is a time consuming and important issue that rarely receives the appropriate resources. This is often a result of recognizing the up-front financial cost of training while failing to recognize the long-term productivity loss associated with no training. Proper training also has a direct and immediate effect on the quality of the test results. It is clear that, given the complexity of the issues WinMATE addresses, multiple levels and methods of training will be required on an on-going basis to minimize overall costs to the end users.

Various training applications, methods, and types of information have been examined and incorporated into the training outline developed under Phase I. The results of the needs analysis will be used to guide the development of the WinMATE software and training system to ensure that we address all aspects of developing a commercially successful package.

Technology Review

A considerable amount of time was required to understand and develop strategies for both commercialization and training method development. Information was gathered and assembled in many different ways from many different methods and sources. The following sections summarize some of these efforts.

On-Site Demonstration and Data Acquisition

BRDI met with UDRI and AFRL/MLLMN technical staff members to gain more first hand knowledge of the scope of the software, hardware, techniques, and knowledge base that comprise the WinMATE system. The primary meeting was held with entry-level technicians who demonstrated the procedures used to set up and use the older MATE software. These procedures are fundamentally the same as

those to be used with the WinMATE software and are therefore an excellent starting point for BRDI in understanding the overall system.

System Description

A description of the overall system, its functionality, and its capabilities was developed during the Phase I effort. This description will be used to determine patent strategies and commercialization plans during Phase II.

Component Description

UDRI staff provided various documents and a partial list of components, both purchased and UDRI developed. This list will continue to be developed as work progresses in Phase II. The information will be included in the documentation section of the training and information system developed in Phase II. This list will also be used to guide the strategic initiatives for patent estate and market development of components.

Measurement Techniques and Capabilities

The DCPD features were reviewed and compiled to document overall system performance characteristics. Much of this work will continue on Phase II as the information must be extracted from the code internal documentation.

On-line information Acquisition and Review

An Internet resources review was conducted to identify potential competitors and their position within the relevant markets. Information describing the competitor's and their business situation was compiled and assessed to determine possible commercialization strategies and potential Phase II partners.

On-Site Observation, Demonstration, and Analysis

BRDI and GlobalLearningSystems met, on a number of occasions, with various representatives from the UDRI and AFRL/MLLMN to establish the use, requirements, documentation needs, and training needs for the WinMATE system.

Database Requirement/Code Development

Two fundamental tasks in Phase I were to 1) develop the data and organization strategies required for the WinMATE learning tools and 2) develop a working WinMATE module to perform crack detection using Direct Current Potential Difference (DCPD) techniques. As phase I progressed, it became apparent that shifting the focus of the code development effort to a full-fledged DCPD crack propagation test control module would better demonstrate the capabilities of the WinMATE system while still adhering to the SBIR proposal and commercialization intent. Thus, code development was re-focused on developing a full application-level WinMATE module for DCPD crack propagation testing rather than the simpler multi-point crack detection utility originally envisioned. The functionality of the crack detection utility is, in fact, incorporated in the more capable crack propagation test control module that was developed.

System Performance Specification Development

The initial code development task was to create the system definition and performance criteria for the Phase I deliverable. The expected outcomes of this task were:

- produce a WinMATE software module that performs multiple-channel Direct Current Potential Difference (DCPD) damage detection measurements during HCF crack initiation testing, and
- integrate the software module with new and highly advanced instrumentation to provide unprecedented damage detection capabilities.

The resulting WinMATE software module and DCPD hardware were initially to be used to detect the onset of damage (micro-cracking, local yielding, or other phenomena) at small notches in advanced Gamma Titanium-Aluminide materials. Detection of the onset of damage in these materials is critical to enhancing existing life-prediction methodologies. Early detection of crack precursors would also allow detailed study of the damage progression process and understanding of the various damage modes that may occur in these and other materials.

As noted above, the code development effort was shifted to a more capable WinMATE module with the ability to perform crack propagation testing using DCPD to measure crack length.

WinMATE 2000 Software Module Development

The WinMATE 2000 DCPD software module developed for Phase I included the following functions:

- Sine and triangle waveform generation to produce a servo-controller load command signal
- Continuous load monitoring and command signal adjustment to maintain the desired loads
- Crack length monitoring using an advanced DCPD technique
- Operator interfaces for all test control, data acquisition, and data presentation functions

Advanced DCPD Instrumentation

A significant portion of the Phase I effort was spent incorporating ultra-high-resolution A/D converter technology (26-bits) developed by the Department of Defense for inertial guidance systems. This technology has recently been released into the public domain and has the potential to significantly enhance our ability to detect the minute changes in electric potential associated with crack propagation in the material. Some work has been done in this area during Phase I and a prototype circuit has been built.

Training Method Identification

Phase I studies of existing training methods indicate that a mentor/student type education is currently in use. Using this methodology, the student receives information and training as required in many different formats and approaches. Information, education, and training may come from books, papers, notes, and discussions, mostly on an informal and inconsistent basis. More formal education may occur on an irregular basis in the form of lectures, seminars and conferences.

Customer Base

As previously noted, the WinMATE customer base is very diverse, ranging from industry technicians to university professors with many levels between. Each of these users has different levels of theoretical background, different levels of reference information requirements, and different data output documentation and analysis needs.

Needs Analysis Results

The needs analysis presented earlier has been used to produce a template for a training system that encompasses all aspects of the training requirements. From the entry-level overview to the complicated test set-up wizard - the background information, training, tutorial, and simulation modes of the training tool are all addressed in a multimedia web-based training platform.

Multimedia Approach

All of the requirements identified through the needs matrices and other analyses can be addressed using a multimedia approach on a personal computer. This method of education delivery was used to develop the learning tool demonstration module during Phase I. A portion of this demonstration outline is shown in Figures 4 through 7.

Figure 4 illustrates the options a WinMATE user will have when starting the system. The *WinMATE Overview* option provides background and general descriptive information. The *WinMATE Tutorial*

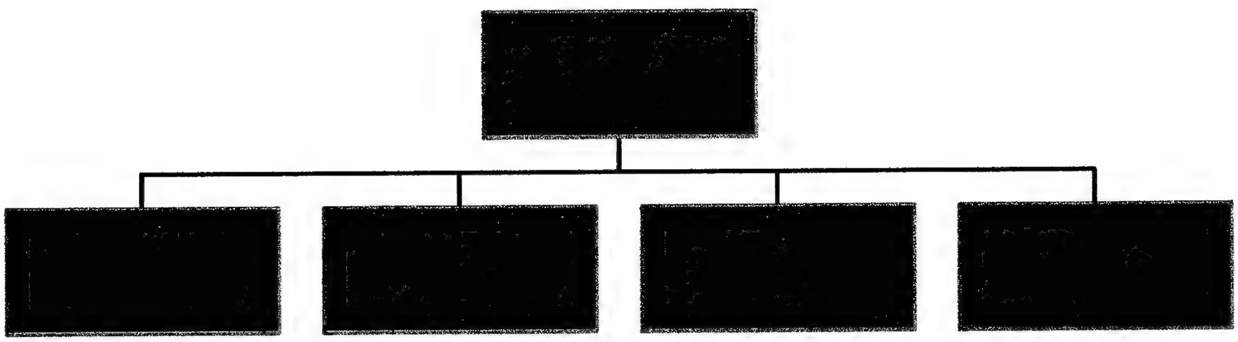


Figure 4. Overall WinMATE System Layout.

option provides instruction and information about the structure, capabilities, and overall uses and applications of WinMATE. The tutorial will cover all aspects and define all parameters, controls, and functions of the program. The *WinMATE Training* option contains extensive training materials and exercises targeted at a range of user experience levels. The *Run WinMATE* option executes the actual test control and analysis program.

Figure 5 shows the selections presented to the operator after entering the tutorial. In addition to the educational and training value, additional features in the tutorial such as material property databases,

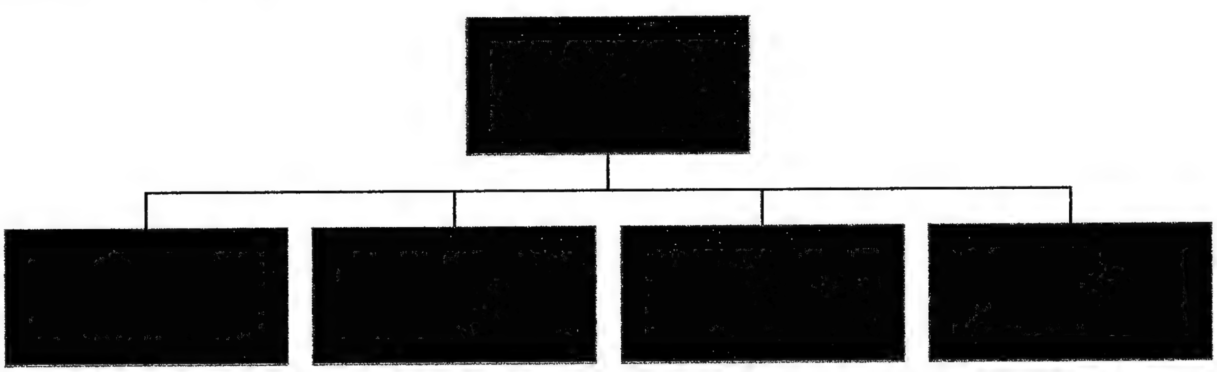


Figure 5. WinMATE Tutorial Schematic.

published industry standards, and other technical references will be provided via database or web links. In addition, system schematics, drawings, and descriptions will be made available as reference information. The tutorial components are briefly described in the following paragraphs.

Measurement Capabilities

Information describing the overall measurement capabilities and potential of WinMATE will be presented. A description in both text and audio formats can be requested to explain the various features of the software.

Data Storage

Instructions concerning file management, data storage, and retrieval will be presented in text, graphical, and audio formats.

Material Data Bases

Links to pre-existing databases will be presented to assist in the selection of test setup parameters.

Hardware Systems

Descriptions of the WinMATE hardware including diagrams, schematics, drawings, and other relevant information will be available for real-time study. These documents are essential for efficient system set-up, maintenance, and field service.

Figure 6 shows the choices presented to the user after selecting the training option. Information at multiple training levels for various users is presented in progressive fashion as shown in the figure. As the user completes the simpler training requirements they are allowed to proceed to more advanced topics and more complex tests types. The training tool will be interactive in the sense that the operator will be able to simulate entire test sequences from start-up to post-test-analysis as

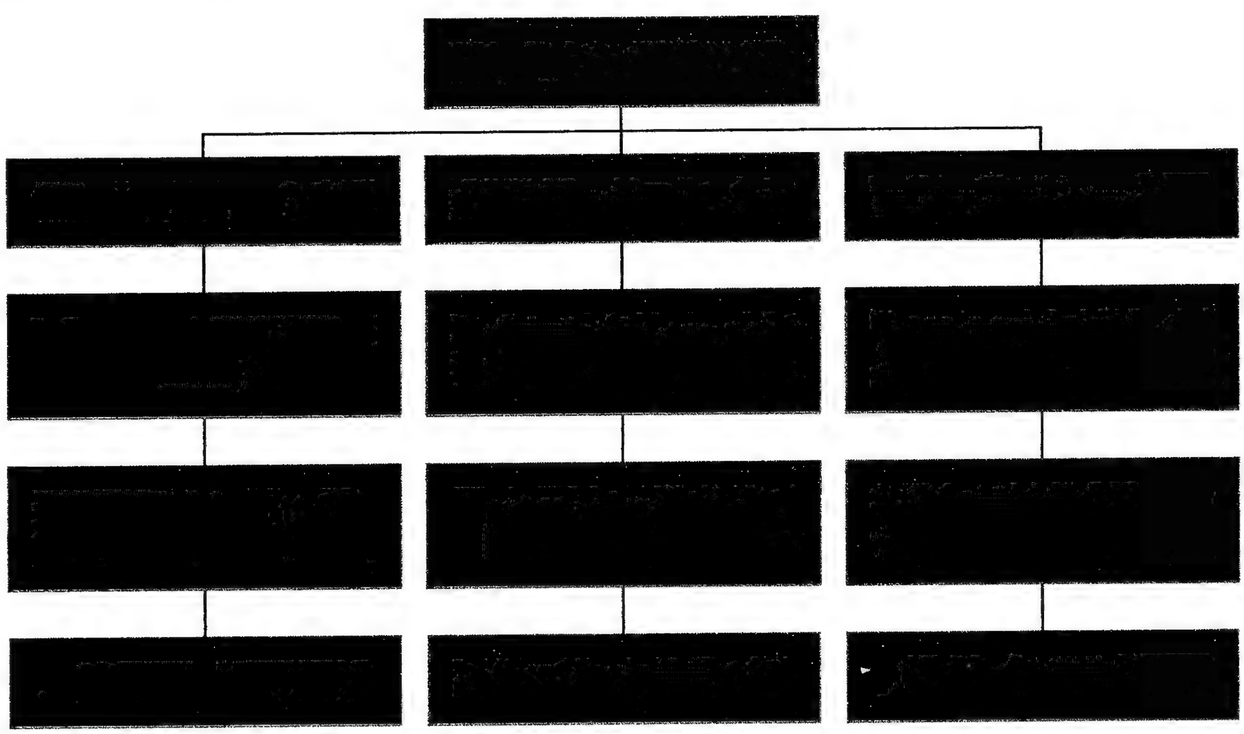


Figure 6. WinMATE Training Levels.

though she were actually connected to a test system. Training will be guided toward three separate levels of user experience - basic, advanced, and expert. The user must be proficient at the basic level before going on to the advanced, and proficient at the advanced before moving to the expert. The procedures and tests listed in each training level in Figure 6 are described in the *Training Progression Plan* section below.

If the operator chooses the Basic Training option in Figure 6 she is presented with the options shown in Figure 7.

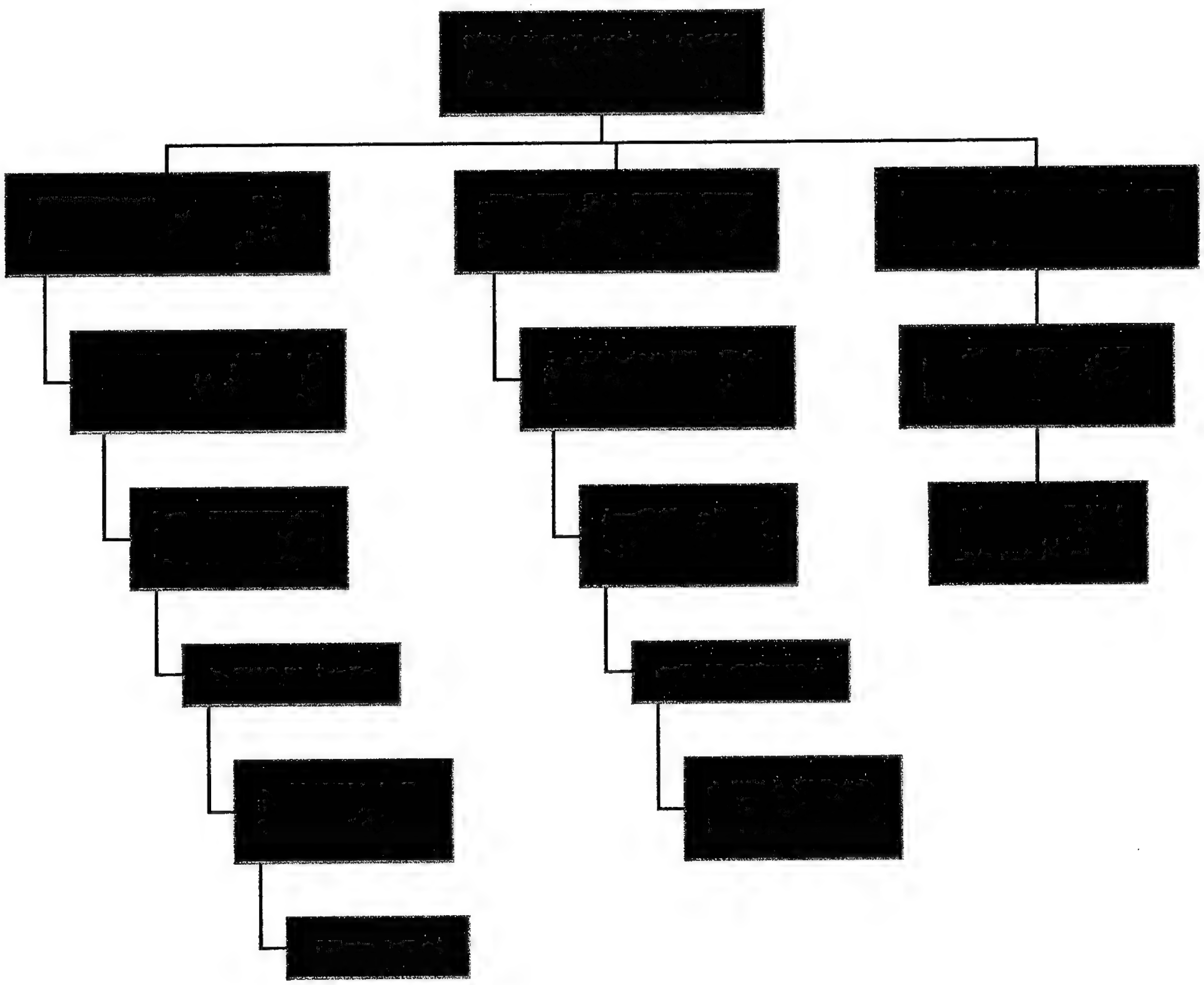


Figure 7. WinMATE Basic Training Level Details.

Training Progression Plan

We have developed a plan for a training system that will step the user through a series of well-defined tests, each step building on the previous one. As noted in the previous sections the progression has three major steps, Basic Proficiency, Advanced Proficiency, and Expert Proficiency. Each proficiency level has multiple stages including lessons and tests.

Basic Proficiency

Completing the basic proficiency requirements means that the user can manipulate the software and hardware in a safe manner and can perform the simplest procedures without direct supervision. Examples of these types of procedures are discussed in the following paragraphs.

Extensometer Calibration

Extensometer calibration consists of physically setting up the subject extensometer with a calibration device, performing preliminary adjustments to determine the parameters for the calibration, performing the calibration, and checking the results. Successful completion of this training phase requires a basic understanding of linear transducer operation and the relationship between the input displacement and the output signal.

Tension Test

The tension test consists of gathering and recording the initial test documentation, specimen preparation and measurement, physical test setup, software setup, performing the test, and analyzing the test results. Successful completion of this training phase requires basic knowledge of stress, total strain, elastic and inelastic strain, elastic modulus, and different test control modes.

High-Cycle-Fatigue (HCF) Test

Much like the tension test, the HCF test consists of initial documentation, specimen preparation, physical test setup, software setup, performing the test, and analyzing the results. In this case, the results may be as simple as the number of cycles required to break the specimen or may include plots of maximum stress versus cycles to failure for multiple tests. Successful completion of this training phase requires basic knowledge of material fatigue, stress, cyclic loading, and (potentially) damage progression.

Advanced Proficiency

Operators working with the advanced proficiency training tools should have previously completed the basic proficiency requirements in a satisfactory manner. Successful completion of the advanced proficiency requirements means that the user can both perform and manually monitor the tests described below to verify correct operation of the software and hardware. Users working at this level must have good working knowledge of the specific concepts associated with the particular test they are performing and be able to apply those concepts to the tasks at hand. Several examples of advanced proficiency tests are discussed in the following paragraphs.

Compliance-Based Fatigue Crack Propagation (FCG) Test

The compliance-based FCG test consists of the same fundamental steps described in the HCF tests above. In addition, the operator must understand specimen compliance, the relationship between compliance and crack length, causes of various anomalies in the load versus displacement data, and when to obtain calibration data for the crack length.

DCPD-Based FCG Test

The DCPD-based FCG test is similar to the compliance-based test except that a different technique is used to monitor the crack length. The operator must understand Ohm's law, specimen electrical isolation, the relationship between DCPD and crack length, causes of various anomalies in the DCPD crack length data, and when to obtain calibration data for the crack length.

Variable Amplitude Loading Test

The variable-amplitude-loading test is similar to the HCF test described above except that the loading amplitude varies from cycle-to-cycle. The operator must understand the dynamic response of the test system and how to adjust the system to obtain the most accurate load excursions at the highest speed possible.

Expert Proficiency

Operators working with the expert proficiency training tools should have previously completed the basic and advanced proficiency requirements in a satisfactory manner. Successful completion of the expert proficiency requirements means that the user can perform, manually monitor, and make fine adjustments during the tests described below. These tests require detailed knowledge of the test system and software operation as well as meticulous preparation and setup. Users working at this level must have broad fundamental knowledge of concepts associated with the class of test they are performing and be able to apply those concepts to the tasks at hand. They must also be capable of anticipating potential problems and prepare solutions in advance. Several examples of expert proficiency tests are discussed in the following paragraphs.

Strain-Controlled Low-Cycle-Fatigue (LCF) Test

The strain-controlled LCF test consists of the same fundamental steps described in the HCF tests above. In addition, the operator must understand mode-switching, behavior of the test system with a physically decoupled control transducer, and other advanced concepts. Operators must be highly skilled in setting up delicate and sensitive instruments as well as the ramifications of and remedies for various types of equipment failure.

Strain-Controlled Thermo-Mechanical-Fatigue (TMF) Test

Probably the most difficult type of test to perform, the strain-controlled TMF test consists of the same fundamental steps described in the HCF tests above with the addition of variable temperature controls and instrumentation. The operator must understand mode-switching, behavior of the test system with a physically decoupled control transducer, interaction of total and thermal strain, load/temperature phase, stress/strain/temperature relationships, and a number of other advanced concepts. As with the strain-controlled LCF test, operators must be highly skilled in setting up delicate and sensitive instruments as well as the ramifications of and remedies for various types of equipment failure.

Training Program Format and Examples

We have selected learningVista, a web-based educational curriculum development tool to be used in the Phase II development. The learningVista software package is used to implement the structure and content for all of the training program functions. learningVista provides a complete framework of technologies, tools, and methodologies suitable for developing online learning applications. The learningVista framework has three important elements – technology, tools, and methodologies.

Technology

learningVista is based on the Java platform-independent application engine. Java Server Pages (JSP) are used to communicate with the end user via HTML, Java classes are used to control system behavior, and Java Database Connectivity (JDBC) is used to facilitate system database access.

Tools

The basic learningVista toolkit is made up of a database, Java classes, and JSP pages. All of these parts can be extended and adapted to provide the functionality desired by the organization implementing the system.

Methodologies

GlobalLearningSystems past experience with respect to use and customization methodologies are built into the framework of learningVista. This provides a tremendous advantage as compared to developing this expertise from the ground up.

Since WinMATE training will require multiple specifications for a learning management system implementation, learningVista is highly suited because it has been designed to be customizable. By using an open Application Programming Interface (API), additional features and integration with external systems are easily addressed. Administrative and instructor reports, connections to external and legacy systems, and customer-specific requirements can easily be added.

Technical Framework

learningVista is a Java-based solution that uses *Java Server Pages* to generate web content, *JavaBeans* to orchestrate system behaviors and business rules, and *JDBC* (Java Database Connectivity) to connect to a database. An open Java API allows for system customization and extension.

WinMATE Training Program Example Pages

The following paragraphs contain examples of web-based pages that are part of the current (demonstration) version of the learning and training tools. All features on these screens are interactive and contain direct links to the various types of training information and documentation.

Figure 8 contains the WinMATE web-based information home page. This page is intended to

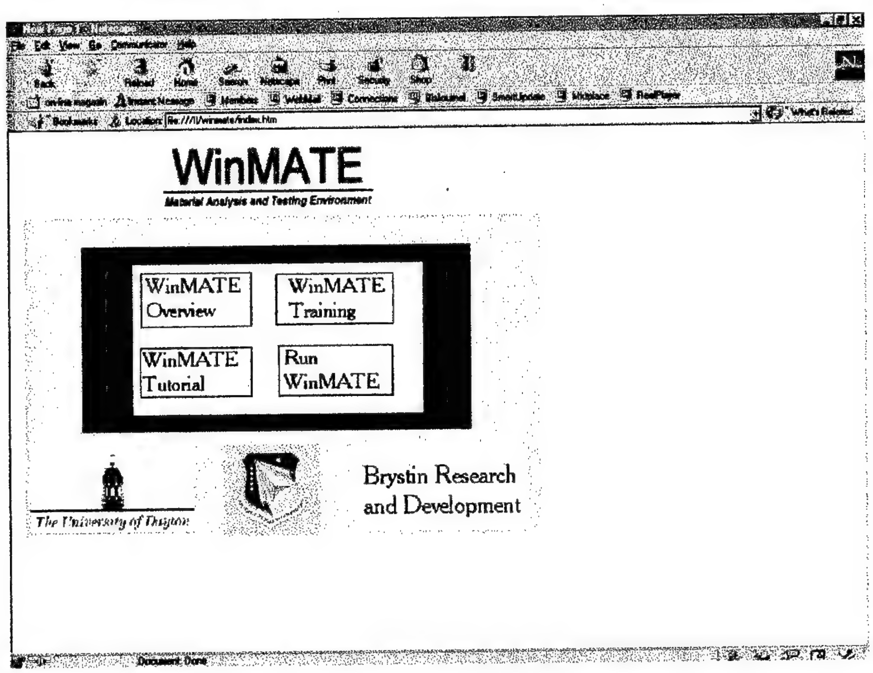


Figure 8. WinMATE Web-Based Information Home Page.

be the starting point for non-licensed users to explore the benefits that WinMATE can bring to their work. Just as importantly, it is the starting point for licensed users to study background concepts, test techniques, industry standards, WinMATE capabilities, and a host of other related information in textual, pictorial, video, and audio formats. System performance, capabilities, and specifications can all be accessed from this page. The main sections of the home page are described in the paragraphs below.

The WinMATE overview section provides a variety of background and general information intended to orient the new user or potential customers. Much of the general capability of the system is described here as well as examples of successful application of WinMATE to various tasks.

The WinMATE tutorial section steps the student through the capabilities of and procedures built into the program in a logical sequence. The choices available at any point in the tutorial are constrained to those functions that are appropriate and logical given the student's progress to that point. For example, let us assume the student has progressed through the tutorial to the FCG test protocols. The first (and simplest) protocol to be learned is the compliance-based FCG protocol. Thus, options associated with alternate FCG protocols would be disabled even though they would normally be available in a real laboratory setting. Within each procedure in the tutorial the student learns how to operate the software in a logical progression as is required when using it in the laboratory. Options are included to tailor the tutorial experience to the industrial or research environment. For example, most industrial testing is sequence-based with a prescribed procedure that is to be followed in a specific order. Research testing, on the other hand, often requires complete flexibility in changing test parameters or even test types based on information from previous tests.

The WinMATE Training section presents information using a variety of media. The home page for the training section is shown in Figure 9. Video and audio instructions are available for test

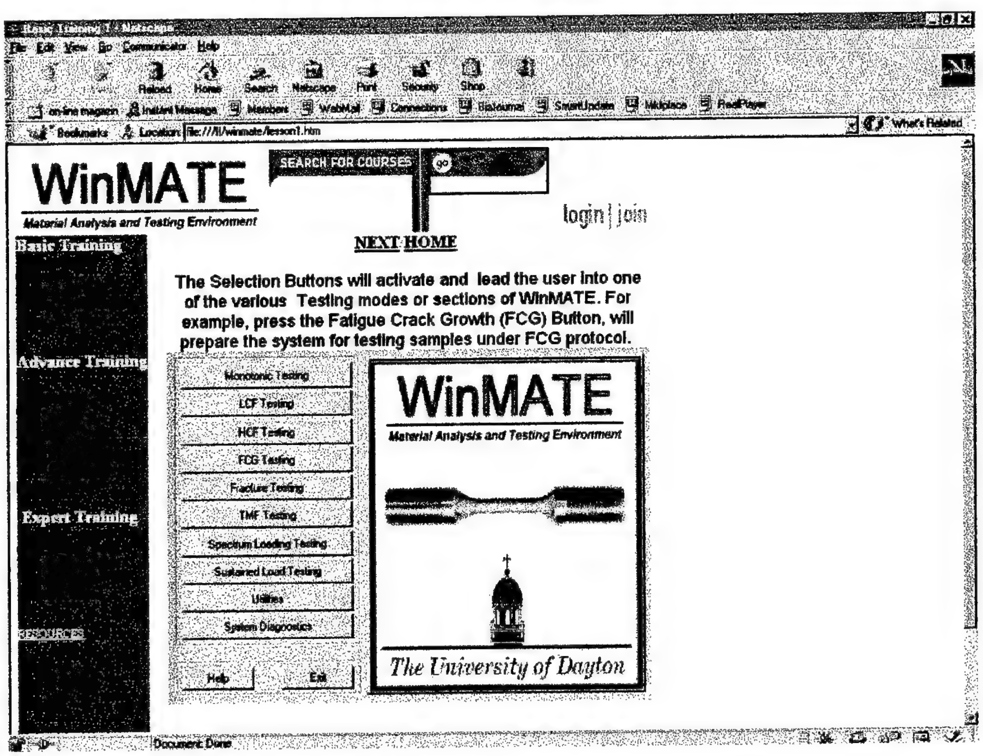


Figure 9. WinMATE 2000 Web-Based Training Home Page.

control, measurement theory, and general WinMATE usage. Lectures concerning broad subject areas are available (typically in a PowerPoint-type format) as well as specific measurement tutorials. Within the training section are courses divided into basic, advanced, and expert levels. Each training level has individual training sections that apply to the various WinMATE test types. Information resources are also made available in this section through links to ASTM and other reference standards, professional publications, and industrial and other web sites. A summary of these training features is shown in Figure 10 and an example of web-based WinMATE resources is shown in Figure 11.

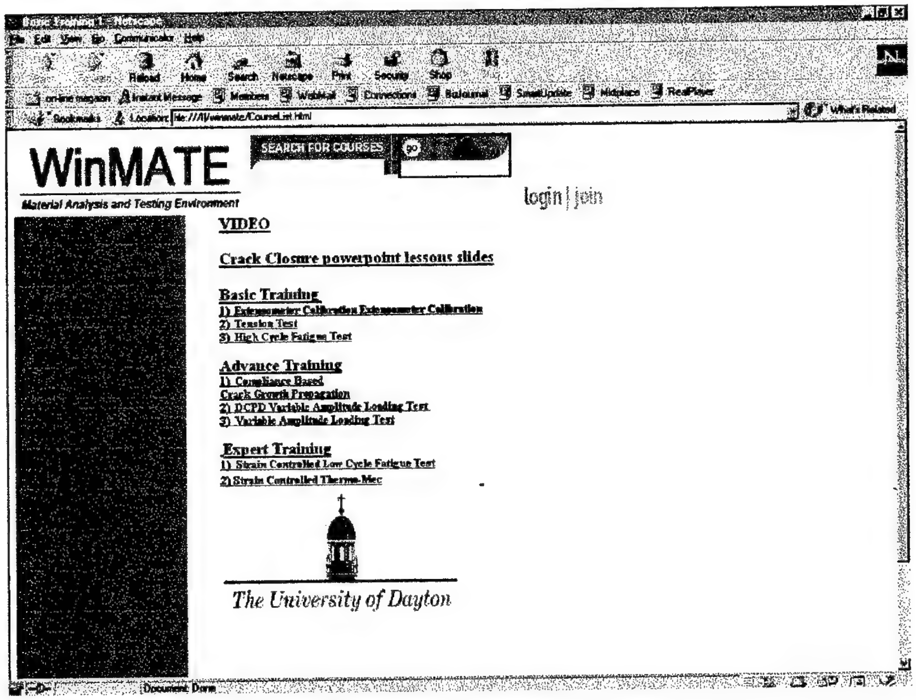


Figure 10. Example of WinMATE 2000 Web-Based Training Features Page.

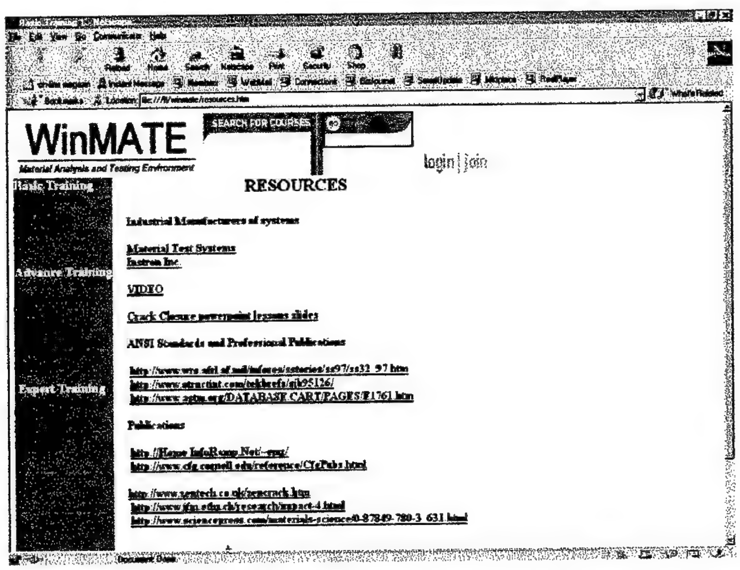


Figure 11. WinMATE 2000 Web-Based Resources Page.

System and Code Development

As part of the Phase I code development effort the following tasks were successfully completed.

1) Updated selected sections of the existing WinMATE code base from the Windows 9x to the Windows NT platform.
2) Developed a demonstration version of the WinMATE FCG DCPD test application module.
3) Developed the basic framework for supporting modules including analytical solutions for stress intensity factors, DCPD versus crack length solutions, and ASTM precracking simulations.
4) Wrote a new device driver module to control and acquire data from the precision 26-bit A/D and the associated serial interface card. These two hardware items were added to the existing core WinMATE hardware specifically to support DCPD data acquisition at high resolution.

Details associated with these tasks are contained in the following paragraphs.

The current version of WinMATE operates under Windows NT and is compatible with Windows 2000. Minor changes will be required to migrate all of the current features to Windows 2000, however, this migration does not make either business or practical sense until the customer base shows a greater percentage of Windows 2000 users.

As of the completion of Phase I, approximately 80% of all existing WinMATE code from previous versions has been converted and debugged under Windows NT 4.0. The remaining existing code is concentrated almost completely in two utility modules and two partially completed application modules. These four modules are not currently in use by the debugging team and will be brought on-line according to the priorities set forth in the Phase II activity.

A demonstration version of the DCPD crack propagation module including working versions of all the major functions was completed and demonstrated as part of the Phase I effort. As the first full-fledged application module developed for WinMATE under Windows NT, this effort will necessarily benefit most, if not all, future application module development efforts. This is due, in part, to the use of programming techniques designed to make the code re-usable. In addition, many of the techniques, algorithms, and functions are directly transferable to similar test control software modules with only minor modifications.

As is typical for a project of this magnitude, some peripheral software development was necessary to produce supporting models and analyses. In particular, a significant effort was necessary to develop an initial, minimal version of the WinMATE Analytical and Numerical Solution (WANS) Library. This library will eventually include Stress Intensity Factor (SIF), crack length from Crack Mouth Opening Displacement (CMOD), crack length from strain, crack length from DCPD, pre-cracking simulation, and several other types of solutions. These solutions will be developed for the currently defined 26 specimen geometry types as well as geometry types added in the future. For the purposes of this Phase I effort we have had to develop the general format of the library as well as SIF and DCPD solutions for two geometries. Accordingly, SIF, crack-length-from-DCPD, and precracking simulation solutions for the C(T) and M(T) geometries were implemented. Of the 22 total stress intensity factor solutions only the C(T) and M(T) are complete. Of the 26 total DCPD solutions for the current geometries, a total of 22 (including the two needed for Phase I) are complete and 4 are in process. Of the 26 total precracking simulation solutions for the current geometries, a total of 4 (including the two needed for Phase I) are complete.

With the addition of the precision 26-bit A/D converters for DCPD measurement we were required to write low-level device driver code for a multi-port serial interface card as well as the direct A/D hardware interface. This work is time consuming due to the strict protocols associated with interacting directly with the hardware. In addition, errors in system-level code often result in system lockup or hard drive corruption. Obviously these problems extend the development cycle. Despite these challenges, however, the device driver code has been completed and debugged and works well with the precision A/D units.

WinMATE DCPD FCG Application Module

Figure 12 contains the current version of the main program control window for the WinMATE DCPD FCG module. The current version of the window includes six major areas of functionality. These are:

- Specimen Test Information
- Test Controls
- Load Control Function Parameters
- Test Limits
- Data Plots and Data Analysis
- Test Status

These functional areas may, of course, change as the software evolves.

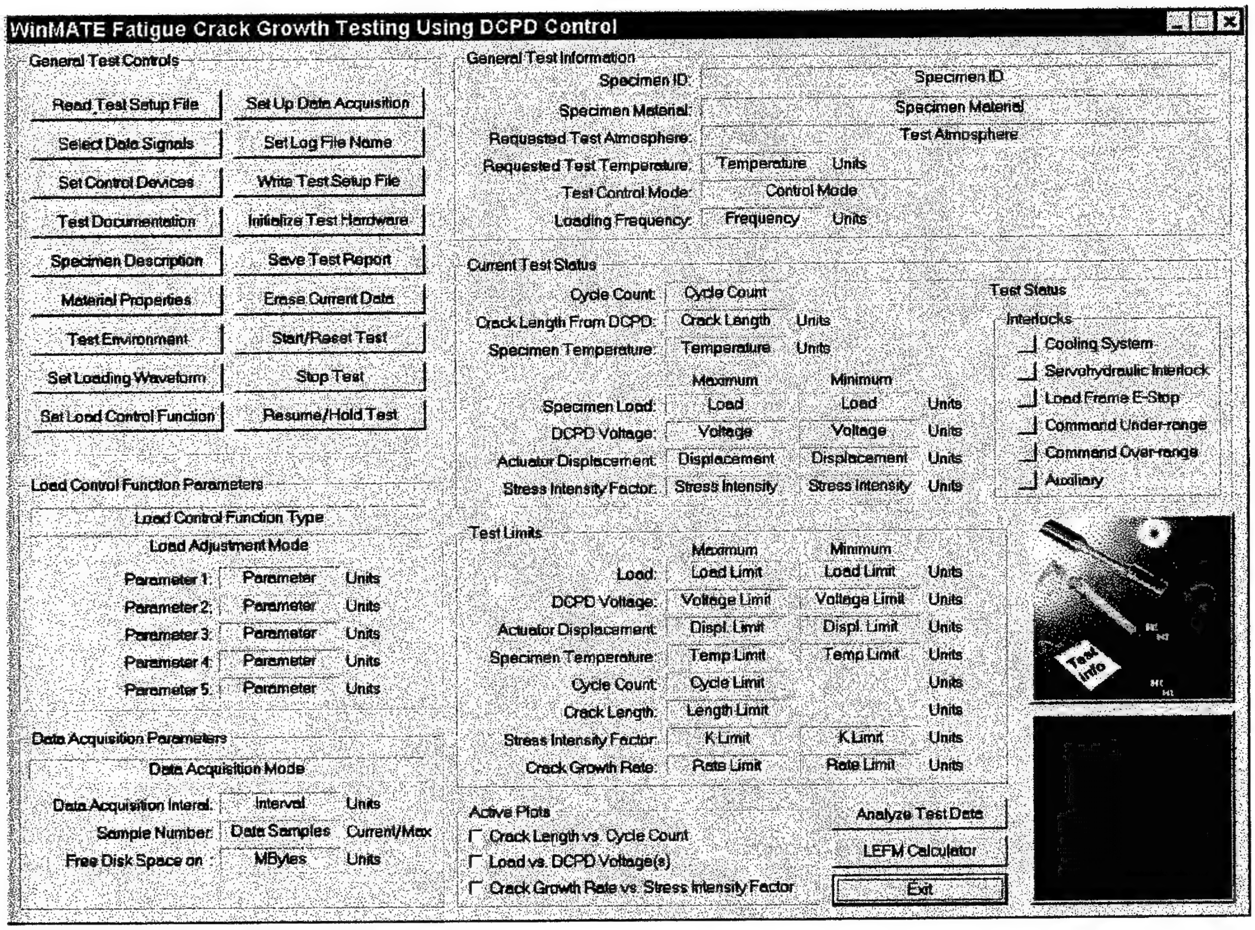
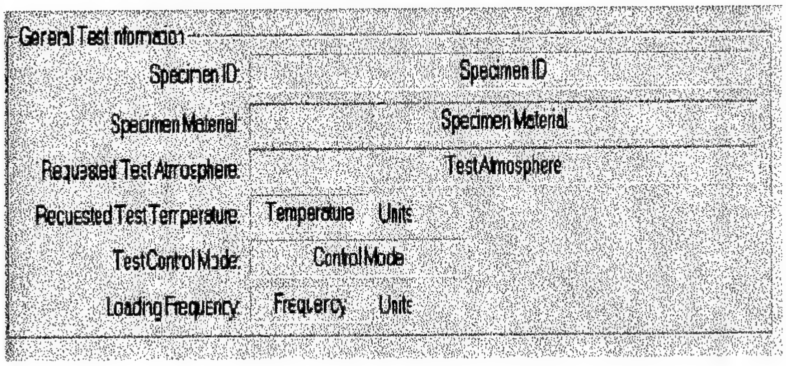


Figure 12. WinMATE DCPD FCG Main Control Dialog Box.

Each window is shown with its self-descriptive functions. All major functions are complete and only require post-Beta debugging at the time of this writing. To maintain a reasonable manuscript length only the primary feature of each function is shown.

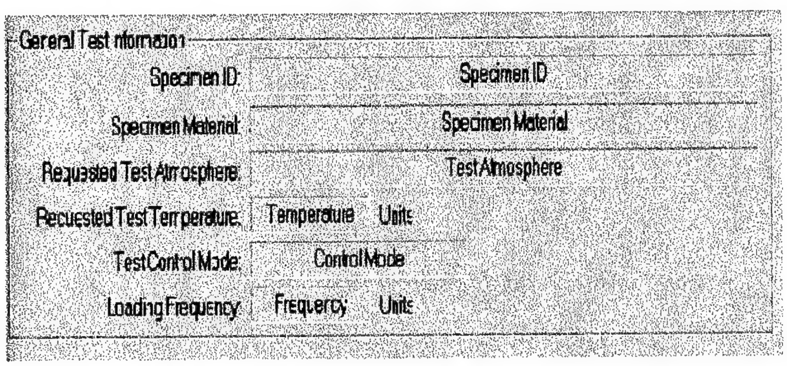
WinMATE Specimen Test Information

Data input for all specimen identification parameters for documentation and test set-up.



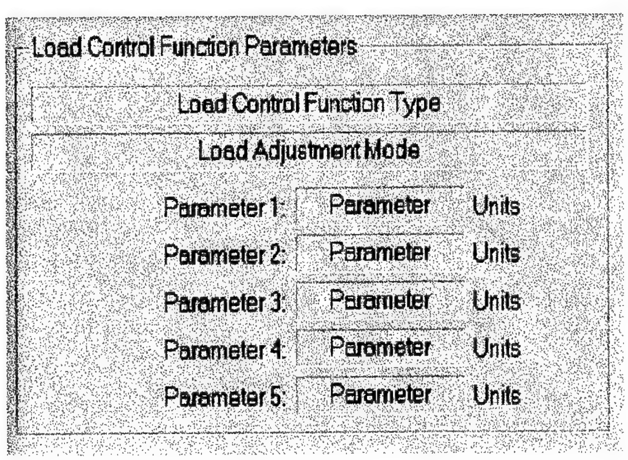
General Test Controls

Controls set-up section for all test variables.



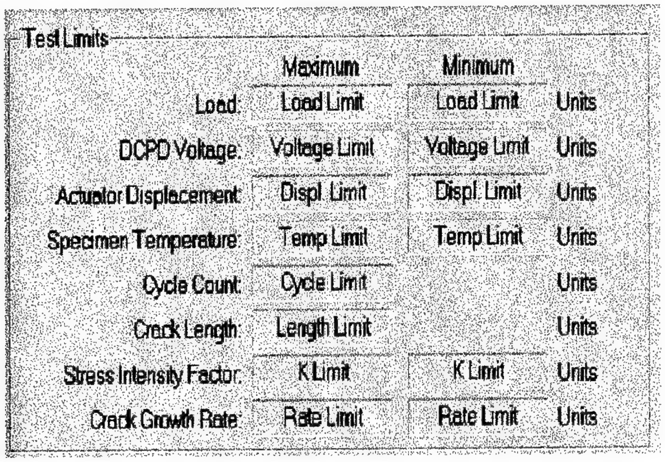
Load Control Function Parameters

Set-up section for load control parameter selection.



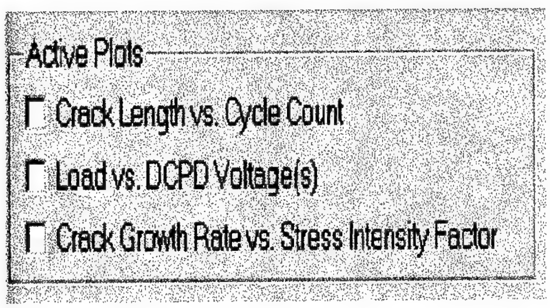
Test Limits

Set-up section for maximum and minimum test limits.



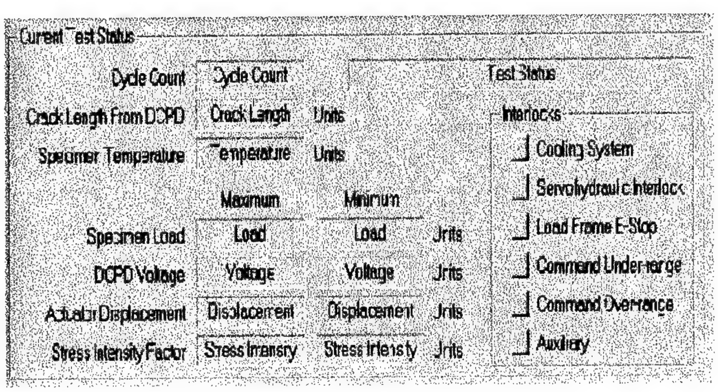
Active Plots

Selection of plots to be active.



Test Status

Test status display area.



Integration of WinMATE Module and Servo-Hydraulic Test System

Appropriate interface hardware including adapter cards, connections, cables, patch panels, and associated gear has been developed and the first set of lab-ready units was tested under real-world conditions. Preliminary tests of the basic data acquisition and control functions have been successful and we anticipate only minor modifications will be necessary to adjust the current designs to production units for commercialization during the Phase II effort.

Integration of WinMATE and Training Module

We have established method, approach and subject matter for the training modules. We have established that a web-based, interactive learning environment will satisfy the needs of all potential users while also providing a documentation system that will address the requirements for all market areas. We have approached this analysis so that both the WinMATE operation system and the training system will have similar appearances and operational features.

Demonstration

On June 29th, 2000 George Hartman demonstrated the features and functionality as well as the overall approach to the WinMATE software.

On October 10th, 2000 George Hartman and Jack Stubbs demonstrated both the Phase I deliverables. The WinMATE program was demonstrated with the functionality of the DCPD module performing all functions. The training system approach demonstrated the multi-media approach to multi-level, multi-user education, training and documentation.

Commercialization Identification

One of the primary purposes of the Phase I effort was to identify all potential markets for the WinMATE software and learning tools. Without a viable market, there would be no purpose in pursuing the Phase II effort. The following paragraphs detail the extent of the market for WinMATE and how we plan to capture a viable share during the commercialization phase of the project.

Markets

There are three major market users and three major technology areas of potential application of the WinMATE system. Each area has similar requirements for the functionality of WinMATE, but all have varied requirements for data handling, analysis, and documentation. Training needs also vary due to the nature of the setting, time to train, training personnel, etc.

Different approaches are also required in each individual area for sales and marketing. Almost all potential WinMATE customers have an established base of existing labs and users. The current market consists of MATE users, MTS system users, Instron system users, and those who have developed their own control systems.

Government Research Lab Application

MATE and various other versions of Windows based MATE have been developed and used over the last two decades at WPAFB. NASA Langley and NASA Glenn, AFIT, and the USAF academy also

have licensed versions. All these users work in a research environment and have the need for easy and continuous upgrade.

University and Major Industry Research Application

Thirteen licenses in Universities and Industry are currently in place for versions of MATE.

Industry Product Development and Quality Control

Currently, product development and quality control markets are lead by MTS and Instron. The industrial market application areas include aerospace, automotive, and consumer products. Each of these markets has great potential for WinMATE. Regulations on consumer products are increasing and the need for automated testing to meet these regulations is increasing.

Industry Technology Areas

The three major technology areas are aerospace, automotive, and consumer products. The largest potential customer base resides with the consumer product companies. Their needs are for dedicated inspection and testing system for research, materials and design testing, and quality control. The training needs are in the entry and advanced levels and the system requirements fall in line with this need. The consumer area encompasses a wide range of product areas, materials, and component configurations.

The automotive market area is also large in size but is narrower in configuration and target materials. Due to federal testing guidelines and standards these systems generally require more complex configuration and testing needs.

The aerospace market is most likely the smallest but most complex market. System configurations must be the most open and capable. The advances in technology will be driven from this segment and applied into the other areas.

Market Size

The total market size was estimated from current established business and estimates of market expansion into the industrial testing segment. A conservative estimate of the potential for license revenue is a multi-million dollar business. Expansion into additional consumer product development businesses shows a positive outlook.

Established Companies

There are really only a handful of companies in this business area. It is highly technical but also requires marketing and sales personnel. The marketing and sales force must be more technically skilled than for most other markets. Of the few companies in the business, Material Test Systems (MTS) in Minneapolis is the largest, best established with annual sales reaching ~$450 million. Instron, National Labs, and a few smaller others also contribute to the industry needs.

Commercialization Study

BRDI met with UDRI representatives to continue the acquisition of information from their technology office. These meetings targeted the University's position on, and coverage of, intellectual property. In addition, license arrangements and a policy for Phase II partnership and commercialization were discussed.

In August, the UDRI delivered to BRDI a list of current MATE licenses, a license position and document format, and a history of UDRI development and license issues for WinMATE. UDRI is now in an appropriate position to begin license negotiations with BRDI on the WinMATE software.

BRDI met with MTS in June to review the SBIR Phase I program, discuss possible partnership and commercialization ideas, and to initiate any appropriate collaborative efforts.

Brystin met with MTS early on August 8th concerning the potential market applications, integration of WinMATE with existing MTS systems, and MTS participation on the Phase II program. The following individuals were in attendance:

Mary Corya	- Products Group Manager
Art Braun	- Division Manager
Dr. Erik Schwarzkopf	- Systems Engineer
John Christiansen	- Applications Engineer and Marketing Manager
Daniel Plazek	- Technology Commerce Engineer

MTS Inc. has agreed in principle that they will participate in the SBIR Phase II effort by providing matching funds and by dedicating some of their staff to work on hardware and hardware interfacing with WinMATE. They will also supply information concerning the sales, marketing, distribution, and field servicing aspects of commercialization. MTS has submitted a proposal to BRDI to participate in the SBIR Phase II program as the potential Phase III commercialization partner.

Business Approaches

BRDI has examined and will continue to examine the many possible business avenues to pursue in commercializing WinMATE. Starting with no limitations in business direction and focus, we looked at the complete spectrum from starting a new company with development, manufacturing, marketing, sales and support, to just licensing software to an existing company. We also investigated many variations in between.

Best Approach

At this point in time, starting a completely new venture to compete head-to-head with established businesses does not appear to be a viable alternative. There are only a handful of competitors but the patent estates are exhaustive and the businesses well established.

WinMATE is also not at the stage where it can be easily marketed and licensed to an existing company. More development is required to get WinMATE to this level. We wish to understand the market better and to build a better system that will be utilized by a larger market share. To this end, we have decided to work with the established market leaders and develop a version of WinMATE that will serve government, academic, and industrial markets.

As previously noted, the market leader is MTS, in Minneapolis. BRDI and MTS are carrying on continuing discussions aimed at forging an agreement that serves the needs and concerns of MTS, BRDI, UDRI, and AFRL/MLLMN.

MTS is proposing to work with BRDI and UDRI on the Phase II in the area of commercialization and market development at no cost to the SBIR contract. MTS will support their end of the agreement from internal funds and will not require any SBIR contractual agreements. The present plan is to have MTS become the Phase III commercialization partner for the SBIR process. Whether this comes to pass will be determined during the Phase II program.

MTS and BDRI have agreed to set up a partnership approach for specifying, evaluating, and implementing WinMATE modules on an individual basis. The individual modules will gradually build an ever-more-capable WinMATE system over time. Each module will be analyzed for marketability and distribution. The entire WinMATE system will be developed as a marketable commercially available package as part of the projected Phase III effort.

Module Launch Scenario

The first modules slated for development will be the DCPD and the Test frame alignment modules. The development and evaluation approach is specified in Appendix I.

Patent/License Strategy

There are many companies and individuals that have filed patents in the material test and device areas. Examples are Duffers Scientific and B. F. Goodrich Company – both have small patent coverage on specific inventions and on more generalized systems and methods. Instron has a small patent estate that covers a few device designs and systems. MTS has the most extensive covering patent estate. The patent field in material testing is very exhaustive in nature indicating that entry in a broad general way would require multiple licenses with multiple companies.

Duffers Scientific Incorporated Patent List

DFI has a limited patent estate both in systems and specific devices. We expect that there are other small companies who have similar coverage.

1 RE 34,843 Signal controlled waveform recorder
2 5,202,542 Test specimen/jaw assembly that exhibits both self-resistive and self-inductive heating in response to an alternating electrical current flowing there through
3 5,199,304 Apparatus for optically measuring specimen deformation during material testing
4 5,195,378 Dynamic thermal-mechanical material testing system utilizing a balanced magnetic field
5 5,092,179 Dynamic material testing system having independent control over specimen deformation and strain rate and a method for use therein
6 4,734,555 Method and apparatus for measuring and controlling indentation in resistance welding
7 4,721,906 One step RMS system
8 4,631,697 Signal controlled waveform recorder
9 4,509,000 Bump-less feedback switching apparatus for use in a servo system

B. F. Goodrich Company Patent List

BFG in addition to other large companies that have application and research groups has a limited patent estate in systems and specific areas. These could be very inclusive and broad in scope.

1. 5,438,863 Universal material test system and method
2. 5,569,858 Viscoelastic material testing system
3. 5,458,002 Viscoelastic material testing system
4. 5,103,679 Method and apparatus for determining the fundamental viscoelastic properties of a material

Instron Patent List

Instron has a small patent estate, with a little coverage of their test frame. They also have a few extensometer and transducer patents.

Apparatus and System Patents

1. RE36,392 Test frame
2. D394,015 Hardness tester
3. 5,616,857 Penetration hardness tester
4. 5,567,866 Side load tester
5. 5,511,431 Structure testing machine
6. 5,413,306 Test frame
7. D351,804 Stress/strain materials testing instrument

Devices, Sensors, Components

1. 5,606,515 Sensor conditioning circuitry for use with electrically excited transducers
2. 5,454,174 Position setting device and securing arrangement for an extensometer
3. 5,440,934 Test apparatus limit switch assembly
4. 5,329,820 Materials testing grip
5. 4,823,473 Extensometer for material testing machine
6. 4,721,000 Axial loading material testing
7. 4,194,402 Testing machine grip
8. 4,160,325 Extensometer
9. 3,943,342 Coarse and fine electronic ramp function generator

MTS Patent List

MTS has an extensive patent coverage of material test systems, apparatus and devices. They cover hydraulic press designs, general material test systems, electronic control systems and load frame designs. Some are specific to a design and some are broader in scope. They also have a small amount of testing method coverage.

Apparatus and System Patents

1. 6,058,784 Material testing apparatus having separated load generating mechanisms
2. D413,506 Support frame for a mechanical wedge grip
3. 5,440,935 Apparatus for combining transducer output signals
4. 5,425,276 Material testing system providing simultaneous force loads
5. 5,115,195 System and method for measuring the absolute position of one body which is constrained to move with respect to another body
6. 5,070,995 Non-contact conveyor feeder system
7. 5,068,779 Degree of freedom digital control system for a hydraulic press
8. 4,907,959 Hydraulic press having integrated column clamps and actuators
9. 4,869,112 Screw-driven actuator for a test frame
10. 4,794,540 Iterative spline function controlled positioning mechanism
11. 4,658,656 Multiple axis test machine reproducing road excited vehicle vibration
12. 4,478,086 Load frame crosshead construction
13. 4,470,787 Hydraulic press
14. 4,457,684 Hydraulic press

Test Method

1. 5,334,933 Variable rejection method for improved signal discrimination in a magnetostrictive position transducer
2. 5,311,124 Emulated analog output magnetostrictive position transducer with set point selection
3. 5,124,626 Sinusoidal signal amplitude and phase control for an adaptive feedback control system
4. 4,802,367 Tensile test controller
5. 4,787,138 Method and apparatus for contact insertion
6. 4,003,246 Specimen crack stress intensity control loop for test device
7. 3,983,745 Test specimen crack correlator

Devices, sensors, components

1. 6,038,933 Multi-axis load cell
2. 5,983,731 Load transducer
3. 5,969,268 Multi-axis load cell
4. 5,959,374 Electromagnetic actuator
5. 5,952,823 Magnetostrictive linear displacement transducer for a shock absorber
6. 5,952,567 Restraint assembly
7. 5,945,607 Test specimen holder
8. 5,819,428 Extensometer structure
9. 5,712,430 Extensometer structure
10. 5,661,446 Electromagnetic actuator
11. 5,640,109 Pulse detector
12. 5,600,895 Extensometer
13. 5,591,944 Overload stop assembly for a load cell
14. 5,587,680 Pulse generator with charge pump
15. 5,532,824 Optical motion sensor
16. 5,491,306 Mass oscillator having an adjustable gas spring
17. 5,339,697 Multi-axis load cell
18. 5,315,882 Six axis load cell
19. 5,313,160 Modular magnetostrictive displacement sensor having a waveguide protected by a material with a thermal coefficient of expansion the same as the waveguide
20. 5,302,023 Localized convection environmental chamber
21. 5,253,522 Apparatus for determining fluid level and fluid density
22. 5,206,586 Magnetostrictive position transducer having square-wave-in-quadrature-output
23. 5,160,750 Differential pitch thread clamp assembly
24. 5,119,569 Multiple gage length extensometer
25. 5,095,757 Specimen grip with remote actuation
26. 5,070,485 Low power magnetostrictive sensor
27. 5,043,685 Threshold compensating detector for magnetostrictive transducer
28. 4,952,873 Compact head, signal enhancing magnetostrictive transducer
29. 4,939,445 Pivoted arm capacitive extensometer
30. 4,905,502 Pressure vessel fatigue test system
31. 4,884,456 High temperature extensometer system
32. 4,879,906 Vibration damped mounting for extensometer system
33. 4,843,888 Self aligning test grip
34. 4,841,226 Capacitive extensometer with curved target surface
35. 4,831,882 Self-supporting extensometer for rectilinear specimens
36. 4,831,738 Capacitive extensometer
37. 4,821,582 Load transducer
38. 4,809,556 Preloading clamp
39. 4,784,564 Reel unloading and handling structure
40. 4,726,226 Distance and temperature measuring system for remote loc
41. 4,690,001 Optical displacement transducer usable as an extensometer
42. 4,679,591 Servovalve drive electronics improvements
43. D290,014 Specimen grip
44. 4,640,138 Multiple axis load sensitive transducer
45. 4,607,531 Torsional-axial extensometer with additional restraint to limit unnecessary movements
46. 4,602,555 Preloaded table coupling
47. 4,598,420 Optical grid analyzer system for automatically determining strain in deformed sheet metal
48. 4,537,082 Reference frame and hold-down support system for remote supported axial torsional extensometer
49. 4,537,080 Side loading specimen grip

50. 4,537,077 Load dynamics compensation circuit for servohydraulic control systems
51. 4,531,901 Crosshead and bolster spacing control for servo controlled press
52. 4,528,542 Waterproof strain gage element system
53. 4,527,335 Averaging axial-diametral strain measuring extensometer
54. 4,509,910 Column clamping assembly
55. 4,507,871 Quick attach retainer for extensometer
56. 4,503,888 Servovalve spool control for digital rotary servovalve
57. 4,491,021 Axial-torsional extensometer
58. 4,475,403 Device to preload loading connections
59. 4,464,937 Extensometer readout circuit
60. 4,458,189 Control mode switching circuit
61. 4,457,072 Crosshead and bolster spacing control for servo controlled press
62. 4,414,854 Rotary actuator assembly
63. 4,336,745 Servovalve flow linearization circuit
64. 4,318,572 Tension-compression swivel joint with hydraulic force reaction
65. 4,316,379 Deep drawing press with blanking and draw pad pressure control
66. 4,290,343 High volume poppet valve with orifice opening speed control
67. 4,274,290 Rapid opening, high flow control valve for hydraulic actuator
68. 4,063,453 Adjustable space frame for testing machine
69. 4,033,566 Pneumatic linear spring device
70. 3,994,540 Pressure balanced bearing with external height control valve
71. 3,992,978 Fluid motor and fluid control means therefore
72. 3,940,975 Extensometer support

Monthly Status Reports

Interim Report #1 April 2000

1.0 Administrative

The following activities were conducted during the month of April.

1.1 Contract start – Contract #5515 initiated April 3, 2000.

1.2 Sub-contract with UDRI – Contract in place April 18, 2000.

1.3 DD250 Form – Invoice form to be used on contract.

1.4 Meeting With Jay Jira – April 27, 2000

2.0 Technical – Interim progress is presented addressing each project task area as defined in the proposal.

2.1 Needs Identification – Project Task 1. The following task list identified from needs analysis results as the technology development initiatives for the Phase I effort.

2.1.1 Produce a working WinMATE 2000 software module that performs multiple-channel Direct Current Potential Difference (DCPD) damage detection measurements during HCF crack initiation testing.

2.1.2 Integrate the software module with new and highly advanced instrumentation to provide unprecedented damage detection capabilities.

Produce a learning tool designed to train operators in the use of the DCPD test module software and DCPD-specific test instrumentation.
Sine and triangle waveform generation to produce a servo-controller load command signal
Continuous load monitoring and command signal adjustment to maintain the desired loads
Damage detection at multiple sites using an advanced DCPD technique
Operator interfaces for all test control, data acquisition, and data presentation functions

2.1.4 Documentation and training module

2.1.5 Test Theory- Material parameters, system parameters and performance, and physical laws place restrictions on system parameters. Knowing these parameters or having the system guide you through set-up routines to determine appropriate parameters will allow the technician to perform meaningful experiments.

2.1.6 Sample Data input – This section will show the user how to input system parameters to set-up and experiment.

2.1.7 Sample Data Acquisition – This section will demonstrate real-time data acquisition, show real system display features and give indications as to what parameters are variable in real-time.

Sample Data Analysis- This section will demonstrate all the data analysis routines available, with operations identified, explained.

2.2. Technology Review – Information on competitive product has been received from MTS, Instron, and Labview. Review and evaluation of features, performance and usability are in progress.

2.3 Data base requirements and approach. The plan is to implement the code in stages as follows:

Hardware interface (device driver)
Application programming interface (API)
Device driver and API test code
Core function application code
Full function application code

This approach has been used successfully on many previous real-time code development projects. In terms of actual function design, the final functionality is defined first with the understanding that changes will be made to accommodate hardware limitations that may be encountered during the actual code development

2.4 Training Method Identification was initiated on April 26. BRDI worked with Andy Lackey on system initialization, parameter identification and overall system use.

2.5 Demonstration to be accomplished at end of program.

2.6 Licensing Situation Meeting With UDRI on April 14, 2000.
Investigating the following topics:
- UDRI Current business model
-Current UDRI License model
-Current UDRI obligations and existing licenses
-Needs for continuation
Results of this task will determine if there are any pre-existing policies or legal issue to satisfy before continuation.

2.7 Documentation formats set-up and in-use.

Interim Report #2 May 2000

Interim Report II May 2000.

Contract F33615-00-C-5515

Brystin R&D, Inc. and The University of Dayton Research Institute.

Durability of Turbine Engine Materials/Advanced Materials Test Methods for Improved Life prediction of Turbine Engine Components.

Task 2. Technology Review

On-site demonstration, and data acquisition
BRDI met again with UDRI technical staff members to gain more first-hand knowledge of the scope of the software, hardware, techniques, and knowledge base that comprise the WinMATE system. The primary meeting was held with an entry-level technician who demonstrated the procedures used to set up and use the older MATE software. These procedures are fundamentally the same as those to be used with the WinMATE software and are therefore an excellent starting point for BRDI in understanding the overall system.

System description – We are compiling a description of the overall system, functionality and capabilities. This will be used to determine patent strategies and commercialization plans.

Component Description- we are compiling a list and description of components both purchased, and UDRI developed. This again will be used for patent strategy and commercialization plans.

2.4. Measurement techniques and capabilities are being reviewed and compiled to address overall system performance characteristics.

2.5 On-line information acquisition and review – review of competitive company's information is being assessed to determine possible commercialization strategies and potential partnering.

Task 4. Training Method Identification

On-site observation, demonstration and analysis
(See task 2.1)

Training progression defined – we are planning to develop a training system that will step the technician through a series of well-defined tests, each building on the previous. The progression is in three major steps, Basic Proficiency, Advanced Proficiency, and Expert Proficiency. Each proficiency level is staged in multiple tests.

Basic proficiency:
4.3.1 Extensometer calibration
4.3.2. Tension test
4.3.3. High-cycle-fatigue (HCF) test

Advanced proficiency:
4.3.4. Compliance-based crack propagation test
4.3.5. DCPD-based crack propagation test
4.3.6. Variable amplitude loading test

Expert status:
4.3.7. Strain-controlled low-cycle-fatigue (LCF) test
4.3.8. Strain-controlled thermo-mechanical fatigue (TMF) test

Task 5. WinMATE Module Development

Low-level code development for the DCPD hardware interface with the microcomputer has started. A working version of the code is anticipated by the end of the first week of June. We decided to develop initial operator interface code to have draft examples of the high-level code as early as possible in the program. This will be used to initiate training program development.

Appropriate adjustments in the code development schedule have been made. In addition, some replacement computer components have been purchased to speed up the code development as much as possible. These adjustments and hardware enhancements will allow us to meet both the need for an early draft of the operator interface code and the need to have the low-level code in place before too much work is done at higher levels.

Task 7. Commercialization

7.1. Component and System identification – Is in process as described in section 2.2 and 2.3.

7.2. Patent coverage determination – George and Jack met and compiled a list of current UDRI patent coverage and potential additional patents.

7.3. Patent Search – An initial patent search has been initiated to determine competitive patent estate and to begin to develop the patent strategy.

7.4. Brystin has made contact with MTS to initiate discussion on potential partnerships for commercialization.

Interim Report #3 June 2000

Interim Report III June 2000
Contract F33615-00-C-5515
Brystin Research and Development Inc. and UDRI
Durability of Turbine Engine Materials/Advanced Materials Test Methods for Improved Life Prediction of Turbine Engine Components.

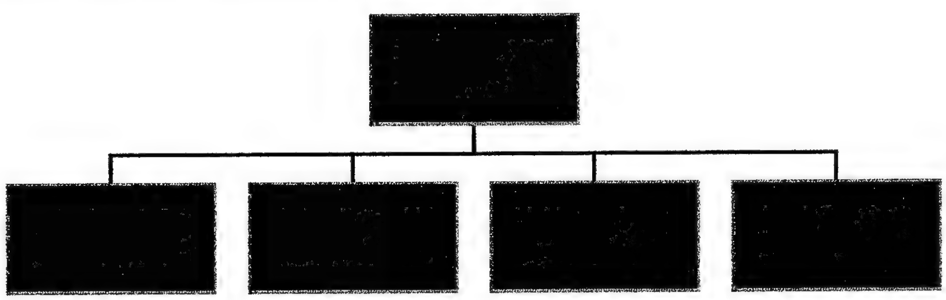
Task 5 Systems Development

Initial application-level code development for the WinMATE FCG DCPD test application module is approximately 80% completed. It is anticipated to have an alpha version of the module in the laboratory for debugging by July 10th. A demonstration version of the module has been developed to continue developing the learning tool based on the latest operator interface.

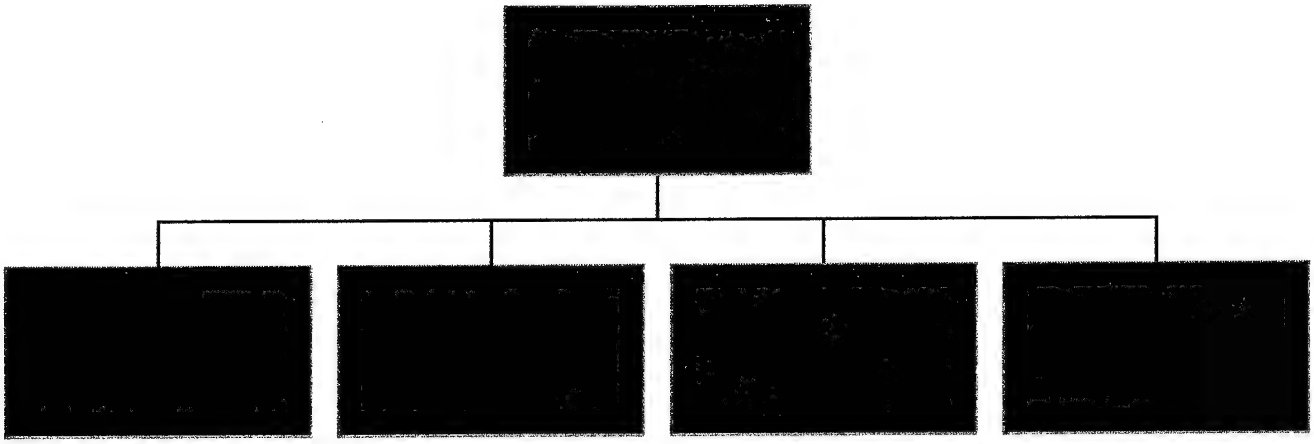
As is typical for a project of this magnitude, some peripheral software development has been necessary to produce supporting models and analyses. In particular, a significant effort has been necessary to develop an initial, minimal version of the WinMATE Analytical and Numerical Solution (WANS) Library. This library will eventually include Stress Intensity Factor (SIF), crack length from Crack Mouth Opening Displacement (CMOD), crack length from strain, crack length from DCPD, pre-cracking simulation, and several other types of solutions for approximately 25 specimen geometry types. For the purposes of this Phase I effort we have had to develop the general format of the library as well as SIF and DCPD solutions for one or two geometries. Task 5.0 is now approximately 50% complete.

Task 5.3 Training Module

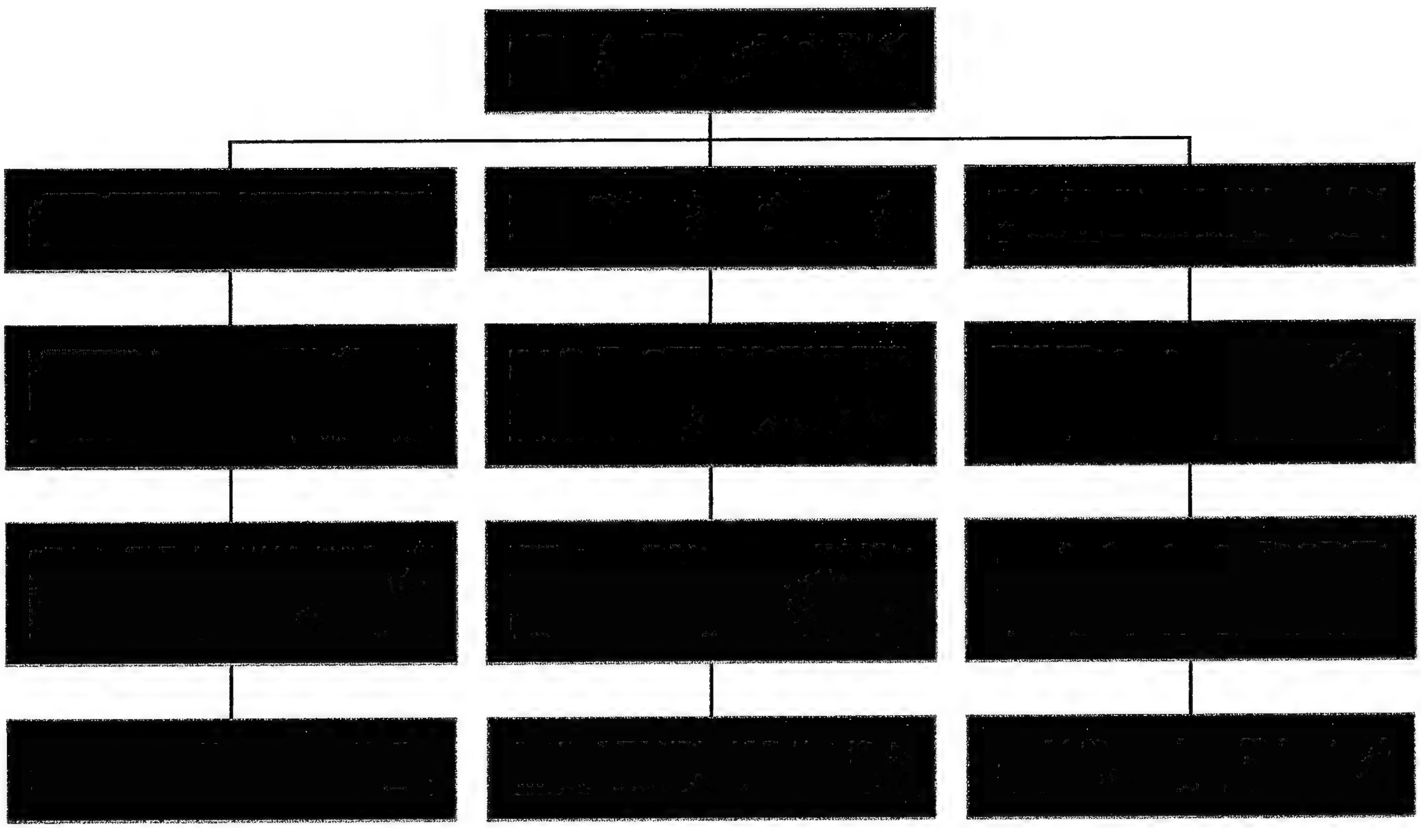
The overall structure of the training module has been developed. It is a multi-level interactive training module that both allows the user to manually step through a logical sequence of instruction and training, and also records the steps reviewed so that the users level of training and level of expertise on the actual systems is tracked and correlated.



The user of Win MATE 2000 will have the option to run the program or Run a tutorial giving instruction and information about the structure, capabilities and overall uses and applications of WinMATE. The tutorial will cover all aspects and define all parameters, controls and functions of the WinMATE program. Selections in the tutorial include:

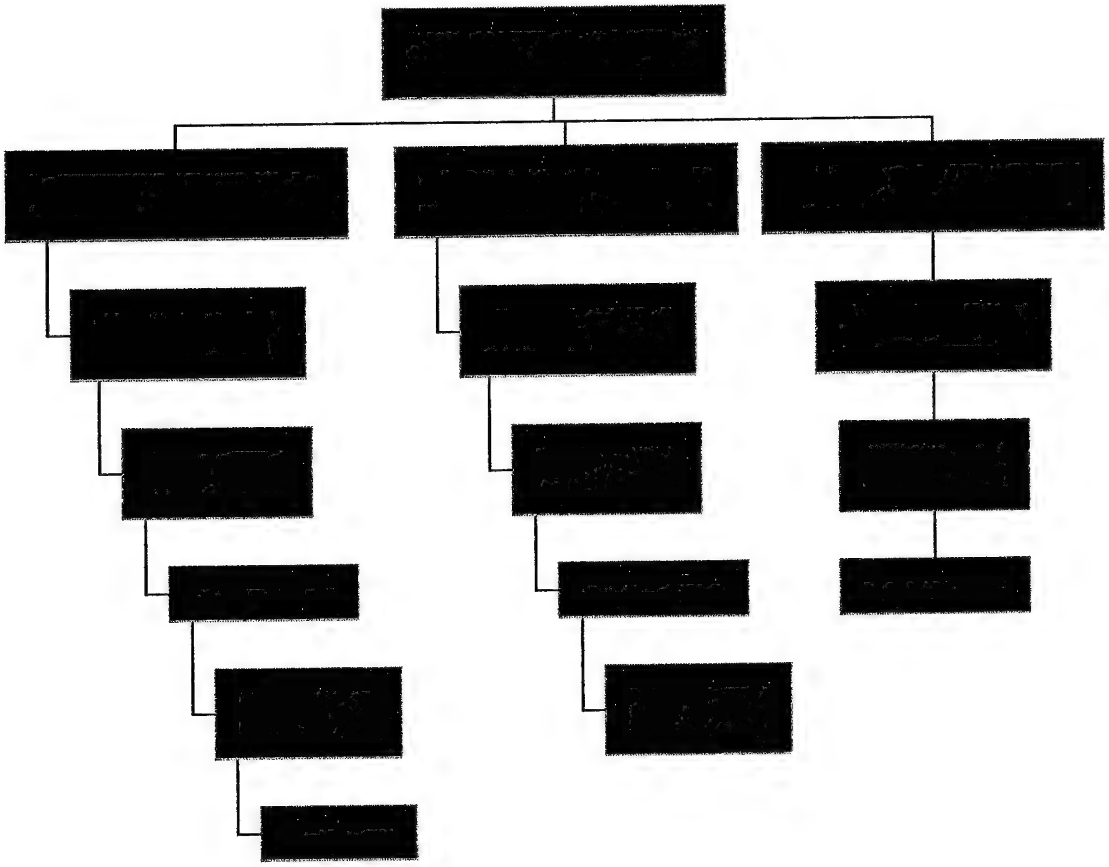


The training program will be interactive in the sense that the operator will be able to simulate the entire sequence of test start-up and function as though he were actually connected to a measurement system. These functions will include:



Training will be guided toward three separate user levels of experience, Basic, Advanced, and expert. The user must be proficient at the Basic level before going on to the Advanced Training. Advanced level performance most also be proficient to be able to progress onto the Expert level.
Many Test modules will be developed to simulate the full functionality of the WinMATE Software.

Each training module will logically step and guide the user through the normal method of using the WinMATE software allowing the user to insert parameters, test set-up, etc. and then actually seeing the theoretical results of the set-up.



Task 7.0 Commercialization

BRDI met with MTS in June to review the SBIR program, discuss possible partnership and commercialization ideas, and to initiate any possible collaborative efforts. MTS Inc. has agreed in principal that they would desire to participate in Phase II efforts of the SBIR by matching funds and dedicating some of their staff to work on hardware and hardware interfacing of WinMATE. They would also supply the potential commercialization aspect of sales, marketing, distribution, and field servicing.

We will continue discussion along these lines throughout July and August.

BRDI met with UDRI representative to continue the acquisition of information from the technology office, to determine the University's position and coverage of intellectual property, license arrangements, and policy for Phase II partnership and commercialization.

Interim Report #4 July 2000

Interim Report IV July 2000
Contract F33615-00-C-5515
Brystin Research and Development Inc. and UDRI
Durability of Turbine Engine Materials/Advanced Materials Test Methods for Improved Life Prediction of Turbine Engine Components.

Task 5 Systems Development

Work during the month of July again focused on generating code for the WinMATE 2000 Fatigue Crack Growth (FCG) using Direct Current Potential Difference (DCPD) for crack length measurements testing module and device driver. Substantial work was completed on both the application-level and device driver (low-level) code bases. The University also provided Brystin Research with appropriate hardware and a copy of the WinMATE 2000 software to use in developing the learning tool. Brystin now has access to the latest versions of the developing code, as the operator will see it on the test system.

Task 5.1 WinMATE Software Module Development

Application-level code development for the WinMATE FCG DCPD test application module is now approximately 90% completed. Testing on specimens in the target laboratory test system was not completed by the July 10th, so efforts are focused on the low-level code. This will be needed at about the same time as the application code base.

Toward the end of the process of developing the low-level code for the original DCPD interface board, a compatibility problem was discovered that would prevent that interface from working correctly with the 26-bit DCPD A/D modules. An alternate interface will be received on July 31st. Work will immediately restart on getting the low-level code operating correctly as this is now the limiting factor in completing the inmate 2000 DCPD module.

Work continues on the inmate Analytical and Numerical Solution (WANS) Library. In particular, crack length from DCPD solutions are being generated for a variety of specimen geometries. The SBIR Phase I portion of this work is now approximately 70% complete.

Task 5.3 Training Module

Jack Stubbs met with John Bissman four times to review the training requirements, review training methods and to establish a commonality between existing accepted software training approaches and WinMATE training needs.

We have established the main training approach and have begun the initial demonstration system for Phase I demonstration.

Task 5.4 Integration of WinMate and Training Module

Jack Stubbs, John Bissman and George Hartman had an initial meeting to begin the process of training software and executable software integration. This task will be continued throughout phase II, initial establishment of parameters early on will save much effort later.

Task 6.0 Demonstration

George Hartman demonstrated the current level of development and overall approach to the WinMATE software to the AFRL/MLLN staff. The demonstration went very well showing the extensive capabilities and potential of the new system.

Task 7.0 Commercialization

Brystin has communicated with MTS throughout the month of July, concerning the potential market applications, integration of WinMATE to MTS systems and participation on the Phase II program. Jack Stubbs will travel to Minneapolis on August 8 and 9 to review their facilities and capabilities, meet with their management to discuss potential relationship and phase II participation and to meet with the technical staff that potentially would work with us on the integration and commercialization efforts.

Interim Report #5 August 2000

Interim Report IV July 2000
Contract F33615-00-C-5515
Brystin Research and Development Inc. and UDRI
Durability of Turbine Engine Materials/Advanced Materials Test Methods for Improved Life Prediction of Turbine Engine Components.

Task 5 Systems Development

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Application-level code development for the WinMATE FCG DCPD test application module is now approximately 90% completed. Testing on specimens in the target laboratory test system was not completed by the July 10th, so efforts are focused on the low-level code. This will be needed at about the same time as the application code base.

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Brystin has communicated with MTS throughout the month of July, concerning the potential market applications, integration of WinMATE to MTS systems and participation on the Phase II program. Jack Stubbs will travel to Minneapolis on August 8 and 9 to review their facilities and capabilities, meet with their management to discuss potential relationship and phase II participation, and to meet with the technical staff that potentially would work with us on the integration and commercialization efforts.

Interim Report #6 September 2000

Interim Report VI September 2000

Contract F33615-00-C-5515

Brystin Research and Development Inc. and UDRI

Durability of Turbine Engine Materials/Advanced Materials Test Methods for Improved Life Prediction of Turbine Engine Components.

Task 5.0 Software System Development

Software development during the month of September again focused on generating code for the WinMATE 2000 Fatigue Crack Growth (FCG) using Direct Current Potential Difference (DCPD) for crack length measurements testing module and device driver. Substantial work was completed on both the application-level and device driver (low-level) code bases. Application-level code development for the WinMATE FCG DCPD test application module is now nearly completed. Testing and evaluation started the last week of September. Final modifications will result from discussions after the demonstration on September 28, 2000.

Commercialization efforts focused on discussions with MTS to start determining market sizes and market potential. Additionally, it has been agreed that developing a commercialization partnership over time, addressing individual modules and compatibility issues is the best arrangement for all concerned parties. MTS has delivered to Brystin R&D, Inc. a draft proposal of their desires to assist in commercialization efforts in WinMATE 2000. We have responded with the need for clarification and additional information.

Task 5.4 Integration of WinMate and Training Module

Jack Stubbs and John Bissman have completes the development of a training software module for the demonstration and determination of viability to WinMATE training. This task shows some of the overall usage and potential for the training system, by examples and conceptual approaches, that will be developed in Phase II.

Task 6.0 Demonstration

Demonstration of the WinMATE functionality and training development is scheduled for September 28, 2000.

Task 7.0 Commercialization

BRDI and MTS have been discussing and iterating and draft proposal from MTS concerning the potential market applications, integration of WinMATE to MTS systems and participation on the Phase II program.

Task 8.0 Documentation

BRDI and UDRI started assembling the final report for the conclusion of Phase I program and the proposal outline for Phase II effort. Attached is an outline of the Phase II proposal including review section that flows from the final report.